Human Research Program
Integrated Research Plan

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Behavioral Health and Performance

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1.0 INTRODUCTION AND BACKGROUND

The Human Research Program (HRP) delivers human health and performance countermeasures, knowledge, technologies, and tools to enable safe, reliable, and productive human space exploration. This Integrated Research Plan (IRP) describes the program's research activities that are intended to address the needs of human space exploration and serve HRP customers. The timescale of human space exploration is envisioned to take many decades. The IRP illustrates the program's research plan through the timescale of early lunar missions of extended duration.

The document serves several purposes for the Human Research Program:

1. The IRP provides a means to assure that the most significant risks to human space explorers are being adequately mitigated and/or addressed,
2. The IRP shows the relationship of research activities to expected outcomes and need dates,
3. The IRP shows the interrelationships among research activities that may interact to produce products that are integrative or cross defined research disciplines,
4. The IRP illustrates the non-deterministic nature of research and technology activities by showing expected decision points and potential follow-on activities,
5. The IRP shows the assignments of responsibility within the program organization and, as practical, the intended solicitation approach,
6. The IRP shows the intended use of research platforms such as the International Space Station, NASA Space Radiation Laboratory, and various space flight analogs.
7. The IRP does not show all budgeted activities of the Human research program, as some of these are enabling functions, such as management, facilities and infrastructure.

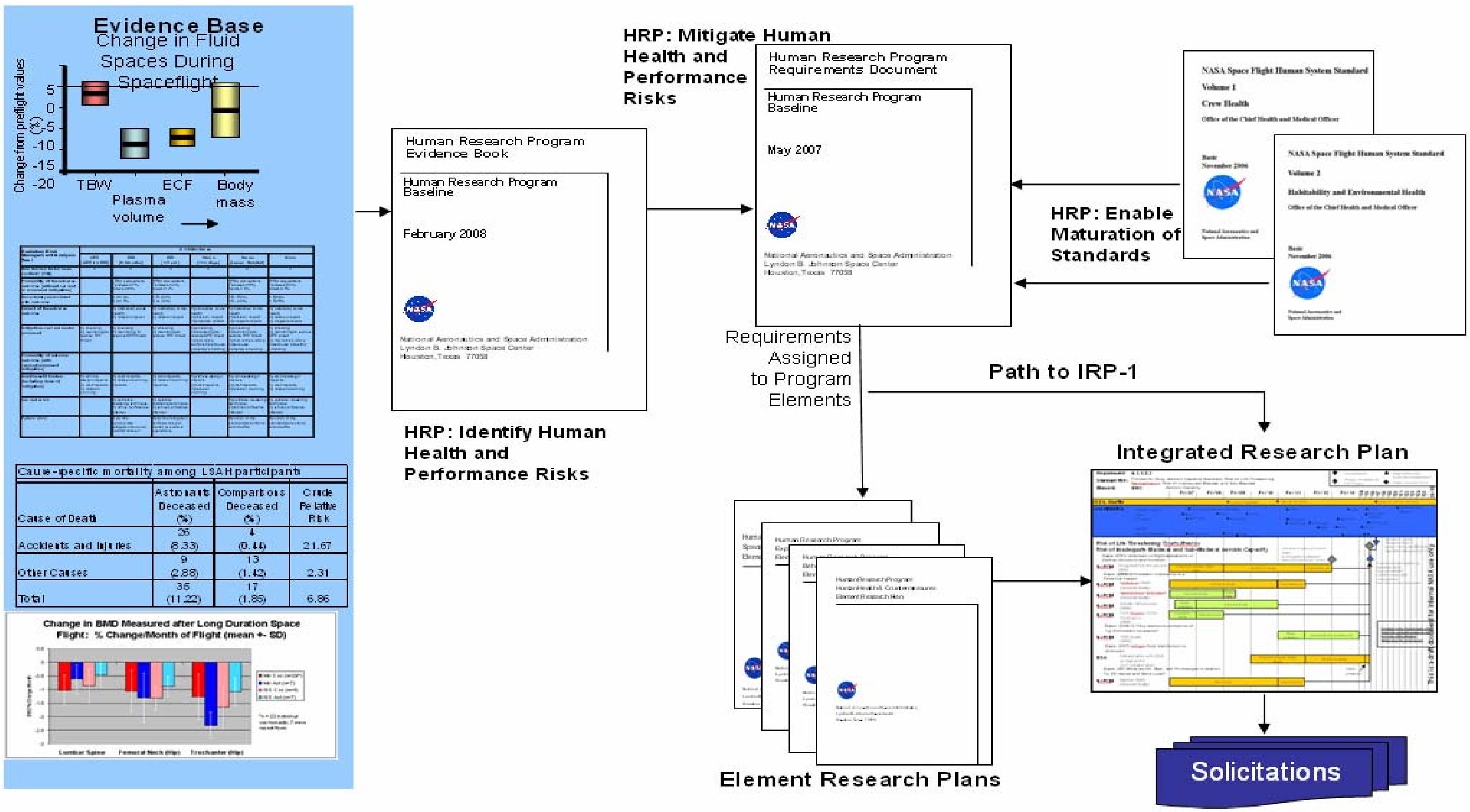
1.1 Context of the Integrated Research Plan

There are three foundational documents to the HRP:

- The Program Requirements Document (PRD)
- The Evidence Book
- The Integrated Research Plan (IRP)

The PRD describes the high-level requirements that the program must meet. The Evidence Book provides the scientific basis for the risks that are contained in the PRD, and the IRP describes the approach to addressing the requirements in the PRD. The relationship of these key HRP documents is illustrated in the graphic below.

HRP REQUIREMENTS AND CONTENT ALIGNMENT



1.2 Program Requirements Document

The HRP PRD documents WHAT risks and standards the HRP addresses. The top-level requirements on the Human Research Program are maintained in the Exploration Systems Mission Directorate (ESMD) Exploration Architecture Requirements Document (EARD), ESMD-EARD-08-07 Rev.-. The purpose of the EARD is to translate the expectations of stakeholders, both outside and inside NASA, for the next generation U.S. Space Exploration mission, into requirements that will flow down to the implementing organizations. The EARD carries the following top requirements for the HRP:

- [Ex-0061] NASA's Human Research Program (HRP) shall develop knowledge, capabilities, countermeasures, and technologies to mitigate the highest risks to crew health and performance and enable human space exploration.
- [Ex-0062] NASA's HRP shall provide data and analysis to support the definition and improvement of human spaceflight medical, environmental and human factors standards.
- [Ex-0063] HRP shall develop technologies to reduce medical and environmental risks and to reduce human systems resource requirements (mass, volume, power, data, etc.).

The PRD decomposes those requirements into lower level requirements that can be allocated to the HRP Element level. It is comprised of two main sections, Standards and Risks.

1.2.1 Standards

The PRD requires that the HRP make recommendations for updates to the Space Flight Human System Standards (SHSS). The SHSS, Volume 1 was first baselined in March 5, 2007 by the Office of the Chief Health and Medical Officer (NASA-STD-3001, Vol. 1). It describes, among other things, Levels of Care required for human spaceflight missions, and Human Health and Performance Standards for crew members on exploration missions. Essentially, these standards define an acceptable level of risk for human health and performance associated with spaceflight. By comparing these standards with the existing evidence and knowledge base, the HRP can identify and quantify the risks associated with human exploration missions, and derive the research necessary to lower the risk.

SHSS, Volume 2 provides the comprehensive set of requirements associated with Human Factors and Habitability. These standards must be met by the Constellation program in development of each vehicle and supporting equipment utilized in space exploration. Through comparison of these standards with the state of the art in engineering design, the HRP can identify areas where research is necessary to help the Constellation program meet these requirements.

The HRP has two main responsibilities concerning the standards. In some cases the SHSS have a wide band of uncertainty. In these cases, the HRP must conduct research to help refine and narrow the uncertainty associated with the standard. In other cases, emerging evidence or knowledge may indicate that the standards are not written in a way that captures a complete set of relevant considerations. In these cases the HRP is required to inform the modification of the standard. Additional research may be required to facilitate this.

1.2.2 Risks

The PRD decomposes the top-level requirements into the specific risks and standards required to be addressed. It allocates the requirements of addressing each the risks and relevant standards to the appropriate Element within the HRP. The PRD, however, does not establish priority for the risks.

The risks in the PRD are arranged in two groups (“Table 1” risks and “Table 2” risks) based on the level of available evidence; Table 1 risks are those for which substantial evidence exists, while Table 2 risks are of concern that cannot be supported or refuted by available information. This Integrated Research Plan addresses each or of risks in the PRD in the priority order described below.

1.3 Evidence Book

The HRP Evidence Book documents WHY the risks are contained in the PRD. It is the record of what the state of knowledge is for each risk in the PRD and provides the basis for analysis of the risk likelihood and consequence. As such, the Evidence Book makes these important data accessible and available for periodic review.

The documentation of evidence for each risk in the PRD is in the form of a brief review article that is aimed at a scientifically-educated, non-specialist reader. The body of each risk review contains a narrative discussion of the risk and its supporting evidence. Declarative statements concerning the risk are supported by a description of the evidence, whether published or unpublished. Relevant published references are listed at the end of the white paper. Data that are significant or pivotal are summarized in text, tables and charts in sufficient detail to allow the reader to critique and draw conclusions, especially when a published reference is not available. In a similar fashion, the authors indicate whether the data are from human, animal or tissue/cell/molecular studies. Evidence from spaceflight (including biomedical research, Medical Requirements Integration Document [MRID] data, and operational performance or clinical observations) is presented first, followed by ground-based evidence (including space analog research and non-space analog biomedical or clinical research). When evidence is from ground-based studies, authors discuss why these results are likely to be applicable in the space environment, offering available validation information for the use of these ground-based systems.
The baseline of the Evidence Book is anticipated in 2008. The National Academies of Sciences Institute of Medicine will review the evidence white papers to validate that the evidence is adequately and completely described.

As new evidence is gathered, the Evidence Book will be updated. If new evidence indicates that a risk should be retired or that a new risk should be added, the HRP will, after thorough review take the appropriate action to modify the PRD and update the Evidence Book accordingly.

1.4 The Integrated Research Plan

The IRP documents WHAT activities are necessary to fill knowledge gaps, WHEN those activities will be accomplished, WHERE they will be accomplished (e.g. use the International Space Station, use a ground analog), WHO will accomplish them (which project or organization within the HRP), and WHAT is being produced.

1.4.1 Priority to Missions

Three categories of prioritization have been developed for the risks:

1. Desirable
2. Important
3. Critical

Each of these categories is applied to two different mission scenarios, the lunar mission(s) (including the lunar outpost missions) and the Mars mission.

Criticality of a risk for Lunar or Mars mission alone is not sufficient to determine the optimum level of activity (or budget) or timing of research investments. Many other factors combine to determine the critical path: limited availability of certain critical resources like the Space Shuttle and the ISS, or the exceptionally long lead times needed improve understanding and mitigation of radiation risks. All of the factors needed to determine the critical path are not explicitly represented in the IRP, only the resultant research plan.

For example, the retirement of the Space Shuttle will introduce significant logistics constraints to and from the International Space Station (ISS). The ISS has resource limitations such as crew-time, imposing a strong planning constraint on research involving human interaction, or the human as a subject. Given this environment, these complex constraints affect the research planning. Conversely a well developed research plan assures that research that requires space flight conditions are clearly prioritized to optimize the use of the platforms.

For reference, each risk heading in this document is labeled with an abbreviated version of the Lunar X Mars priority.

Criteria for prioritization of the risks applicable to the lunar mission(s) are:

- Desirable to Quantify and Reduce Prior to the Lunar Mission: The absence of data or risk mitigation countermeasures in this area (beyond what is available at the baseline date of this document) would not delay the Lunar mission even if all other elements of the mission were ready (e.g., if the launch systems, EVA systems, landing and life support systems were ready), but quantifying and reducing the risk would reduce the risk for that particular discipline. Engineering or operational workarounds/constraints could be avoided if this risk were quantified and/or reduced.
- Important to Quantify and Reduce Prior to the Lunar Mission. The absence of additional data or risk mitigation countermeasures in this area (beyond what is available at the baseline date of this document) would likely not delay Lunar Mission even if all other elements of the mission were ready (e.g., if the launch systems, EVA systems, landing and life support systems were ready), but would leave the mission with significant residual or unknown risk. Mission Loss or major impact to post-mission crew health could occur if this risk is not quantified and reduced.
- Critical to Quantify and Reduce Prior to the Lunar Mission. The absence of additional data or risk mitigation countermeasures in this area (beyond what is available at the baseline date of this document) would likely delay Lunar Mission even if all other elements of the mission were ready (e.g., if the launch systems, EVA systems, landing and life support systems were ready). The lack of this data or an adequate additional mitigation would leave NASA with unacceptable uncertainty in the residual risk, and/or with unacceptable absolute risk to human health and performance, thus precluding NASA's ability to embark on the mission.

Criteria for prioritization of the risks applicable to the Mars mission(s) are:

- Desirable to Quantify and Reduce Prior to the Mars Mission: The absence of data or risk mitigation countermeasures in this area (beyond what is available at the baseline date of this document) would not delay the Mars mission even if all other elements of the mission were ready (e.g., if the launch systems, EVA systems, landing and life support systems were ready), but quantifying and reducing the risk would reduce the risk for that particular discipline. Engineering or operational workarounds/constraints could be avoided if this risk were quantified and/or reduced.
- Important to Quantify and Reduce Prior to the Mars Mission. The absence of additional data or risk mitigation countermeasures in this area (beyond what is available at the baseline date of this document) would likely not delay the Mars

Mission even if all other elements of the mission were ready (e.g., if the launch systems, EVA systems, landing and life support systems were ready), but would leave the mission with significant residual or unknown risk. Mission Loss or major impact to post-mission crew health could occur if this risk is not quantified and reduced.

- Critical to Quantify and Reduce Prior to the Mars Mission. The absence of additional data or risk mitigation countermeasures in this area (beyond what is available at the baseline date of this document) would likely delay the Mars Mission even if all other elements of the mission were ready (e.g., if the launch systems, EVA systems, landing and life support systems were ready). The lack of this data or an adequate additional mitigation would leave NASA with unacceptable uncertainty in the residual risk, and/or with unacceptable absolute risk to human health and performance, thus precluding NASA's ability to embark on the mission.

Ultimately, prioritization of the risks, the gaps and the activities can be conducted through a Probabilistic Risk Assessment that integrates and compares the reduction of the overall risk to the mission, given different mission scenarios, research approaches, and outcomes. The HRP will use the RMAT tool to categorize and assess the risks and gaps according to priority. At present though, there is not an integrated or validated PRA tool that will allow the use of the RMAT data to do the cross-comparison or the prioritization of risks or gaps. Until the availability of such a tool, the HRP relies on expert opinion, with consideration of the existing evidence. The HRP Science Management Office has the task of prioritizing the HRP research portfolio as described in the HRP Science Management Plan (HRP-47053) Paragraph 3.1.

1.5 Schedule Drivers and Context Considerations for the Reader

Research is inherently non-linear. The one constant about the IRP is that it will change. As knowledge is gained, the required approach changes. This document represents the best plan available at this moment in time. It would be impractical to assume a linear approach with respect to future research plans. The IRP will be revised and updated yearly based on available resources, Constellation and other schedule constraints, and a consideration of new evidence that was gained in the previous year.

The fidelity of the research plan is related to the timeframe for which it is planned. For instance, the fidelity of requirements for the research described in this plan for 2008-2009 is high. On the other hand, the fidelity of requirements for activities listed in this plan beginning in 2020 is lower. The yearly update will allow these descriptions to change as new evidence is considered and key milestones are achieved.

This version (#1) represents the initial definition of an integrated research plan based upon the HRP current research portfolio. Future versions of the IRP should include a more detailed review of the ties of the knowledge gaps to the evidence base for each risk.

NASA has laid out some very specific schedule milestones for implementation of the Vision for Space Exploration (VSE). The Shuttle retirement in 2010, the Orion vehicle in 2014, and the first lunar sortie by 2020 together create urgency for the acquisition of knowledge. The use of the Shuttle and ISS platforms, in several cases, is critical to obtaining the required knowledge to build products supporting longer, more challenging missions. In some cases, research is accelerated to take advantage of the availabilities of those vehicles.

This plan is NOT intended to mitigate risks associated with the ISS. The ISS is used as a platform to conduct research aimed at mitigating risks to the exploration missions. Some of the research may identify countermeasures, engineering or operational solutions that would enhance the ISS and reduce risk in use of that platform. In those cases, the HRP identifies the necessary deliverables and insertion points for the ISS. However, the focus of this document is to identify deliverables necessary to complete the exploration (Lunar and Mars) missions.

This plan includes activities that are more than “Research or Technology Development”. In some cases, the activities reported in this document are not explicitly “research” or “technology development”, but are included to ensure logical completeness in describing those activities necessary to mitigate the risks. Examples are data mining activities, the results of which are pivotal in defining further steps in the research path, and hardware evaluations which would further our engineering approach to mitigating a risk.

Human health and performance risks can best be mitigated through the space system design. The HRP works closely with the Constellation program to communicate the areas of human health and performance risks, and to advise in the engineering and development of the Constellation systems. Mitigation of many human health and performance risks can be accomplished through engineering design and operational constraints, and do not need further research. Decision points in the research schedules are placed to evaluate whether the engineering design approaches are adequate, or whether other countermeasures are necessary. As a rule, engineering should be the first method of dealing with these issues; however, much of the research may continue to be necessary to relieve overly burdensome engineering or operational constraints.

A flight resource analysis is necessary. A key next step for this document is to identify the flight resources required to implement the described research and compare those resource requirements with the projected availability. If a shortfall exists, the HRP will work with the ISS program to develop the appropriate approach. If it is found that the HRP complement of research cannot fit into the available flight resources, the prioritization will be used to identify those investigations most critical to facilitate exploration.

Key Decision Points are built into the research plan. At these points the HRP will evaluate data pertaining to likelihood and consequences and perform risk analysis to determine the proper approach. In some cases likelihood with existing countermeasures will not be high enough to warrant proceeding with more research.

2.0 SUMMARY OF THE RESEARCH PLAN

The development of this document has been evolutionary. The HRP recognizes that the format of this document, while comprehensive in its scope requires an additional high-level summary to facilitate a quick understanding of the overall research plan. Further, the integration of research across discipline lines has yet to be completed. A future version of this section is intended to provide a high-level summary of the research approach and planning for each risk. It will also describe how the HRP is performing the integration of research activities across risks.

For each risk in this document, a summary paragraph, an outline of the major gaps, and a short description of the research approach to fill the gaps will be given.

Many activities described in this document address multiple gaps. A different and easier way of viewing their applicability will help to understand the integrated nature of the particular research approach. This section will capture the activities that address multiple gaps, describe the general approach, how each of these activities relates temporally to the research planning and how it relates to the relevant risks. Examples of these activities are the post-flight functional task performance test, the 6-degree head-down bed rest testing environment, and the lunar bed rest environment.

3.0 ELEMENTS INPUT DESCRIPTION

The format for the Elements' inputs will include graphical depiction via Gantt charts and written discourse to clarify the Element position. Each input follows the same form. The Risk is reported, the Operational Relevance is described, the risk priority is given, the gaps in knowledge are reported with a brief description and for each gap, and the activity or activities necessary to address the gap are described. For each activity, the resulting product/deliverable is described and each required delivery milestone for the deliverable is given along with the required platform and Project or organization responsible for implementing the activity.

3.1 RISKS

Each text description has a description of the risk. These descriptions are verbatim from the Program Requirements Document and are reprinted in the IRP as a matter of convenience for the reader.

3.2 CONTEXT OF RISK FOR EXPLORATION

After each risk description is a paragraph entitled Operational Relevance and Risk Context. In this paragraph, a description of the relevance to the exploration mission is given. This section gives the context within which the research plan is built for that risk and describes the need for the research at a very high level.

3.3 PRIORITY

The priority for the risk for each mission is given. This priority uses the criteria described in the section above.

3.4 GAPS

Gaps in our knowledge or evidence base exist for each risk. These gaps have several different forms. A gap may exist in our evidence base, which leaves greater uncertainty regarding the likelihood of the risk. A gap may exist in the identification of the appropriate countermeasure. For others, the gap may be in the flight validation of the appropriate countermeasure. For the purposes of this IRP, the gaps are not delineated by type; rather they are simply identified as a gap that must be filled before the risk is mitigated. In some cases, the gap may not require research to fill it, but rather can be avoided altogether through selection of a specific Constellation design.

3.5 ACTIVITIES

Under each gap are one or more activities required to fill the gap. The activity is named and a short description is given. In some cases an activity can address multiple gaps perhaps across many different risks. To limit the size of this document, an activity that addresses many different gaps is named and described once and the description is referred to in the other gaps that it is intended to fill.

3.6 PRODUCT/DELIVERABLES

Each activity is designed to culminate in a product or deliverable. These deliverables are structured to feed into the Constellation program, the Office of the Chief Health and Medical Officer or the Mission Operations Directorate. Several different types of deliverables exist. An activity can result in recommended updates to the Space Flight Human System Standards. In that case, the HRP forwards the recommendation to the Chief Health and Medical Officer for incorporation into the standards. Some deliverables result as information to a particular operations constraint. The HRP will identify the appropriate Mission Operations organization (Medical Operations, Flight Operations, Ground Operations or the Operations Office) within the Constellation Program to which changes in their operational approach will be recommended. Other deliverables take the form of requirements. In those, the HRP will recommend requirements changes for the Constellation program documentation. Another deliverable takes the form of countermeasures. These are approaches, whether physical or pharmaceutical, that is used to mitigate the risk.

3.7 REQUIRED DELIVERY MILESTONE

Key milestones within the Constellation Program development drive the required date for the HRP deliverables. For instance, design requirements typically must be defined by the appropriate System Requirements Review. Design solutions and technology typically must be defined to a TRL6 level by the Preliminary Design Review. This section documents the schedule drivers for the delivery milestones.

3.8 REQUIRED PLATFORMS

This section defines the platform required to perform the research. Platforms can be designated as Ground analog environments, such as NEEMO, Antarctica, etc, or the platform may be a space based one, such as STS or the ISS. Also, the lunar surface is a platform that is anticipated in some research efforts.

3.9 PROJECT OR ORGANIZATION RESPONSIBLE FOR THE IMPLEMENTATION OF ACTIVITY

Within the HRP elements, there are one or many projects chosen to implement the element research plan. The project is identified in this section. In some cases, organizations outside the element are responsible for implementation of the research, such as the NSBRI or even an international partner. These organizations are identified in this section.

This section identifies the project with primary responsibility for implementing the activity. In some cases the project is not within the element responsible for the risk. The element responsible for the risk will coordinate with the appropriate project in those cases.

Discipline teams include participation of operations personnel, the NASA research discipline experts, and the NSBRI. In several cases, the primary responsibility is shown as that of NASA, however, that does not mean that the NSBRI is not participating at all. The NSBRI participates through the discipline teams as well as through future solicitations.

3.10 GRAPHIC INPUT

Each graphic is supported with text that provides a more thorough level of detail. Figure 2 shows an example Gantt chart and labels each section of the chart. Each Gantt chart is associated with one of the 33 PRD Risks. The element to which the risk is allocated is identified in the upper left corner. For each risk, the research gaps are identified by name and number along the left side. Under each gap are the identified activities required to fill the gap. Each activity is identified by name and the acronym of the project or organization responsible for implementing the activity. In some cases, the organization responsible for implementing the activity may not be directly controlled by the element responsible for the risk. The schedule of each activity is shown on the graphic and an arrow shows deliverables resulting from the activity. The activities are color coded, gold for STS/ISS activities, green for ground activities, purple for data analysis, and yellow for Lunar activities. Cross-hatched colors represent activities conducted by the NSBRI. Small text identifies each deliverable. A number on each text deliverable description relates the deliverable to the need date, shown by the gray numbered arrows at the top of the chart.

3.11 DECISION POINTS

Several key decision points have been placed in the plan. At these key decision points the appropriate forward path for the research will be reevaluated. The decision points are cast in a "Yes/No" form, and it is anticipated that at these points, the responsible element will review the overall current state of the evidence, and review the appropriate approach to the forward plan. Where applicable, the Science Management Office will concur and, if necessary, the appropriate Project Standing Review Panel may be convened to deliberate and make recommendations. Criteria for making the decision will be determined on a case by case basis and will be consistent with the overall management structure documented in the Science Management Plan. The process will be implemented consistent with the Program Implementation Plan. In many cases, an activity addresses more than one risk.

RISK OF PERFORMANCE ERRORS DUE TO POOR TEAM COHESION AND PERFORMANCE, INADEQUATE SELECTION/TEAM COMPOSITION, INADEQUATE TRAINING, AND POOR PSYCHOSOCIAL ADAPTATION -D X I

Human performance errors may occur due to problems associated with working in the space environment and incidents of failure of crews to cooperate and work effectively with each other or with flight controllers have been observed. Interpersonal conflict, misunderstanding and impaired communication may impact performance and mission success. The history of spaceflight crews regarding team cohesion, training and performance has not been systematically documented. Tools, training and support methods should be provided to reduce the likelihood of this risk and improve crew performance.

Operational Relevance Assessment and Recommendations

While little empirical data have been collected regarding the impact of interpersonal and intrapersonal factors on spaceflight performance, it is possible that crew conflict could jeopardize a long duration Exploration Missions. Reports from MIR reveal that several missions may have been terminated earlier than planned due to interpersonal frictions between crewmembers, and some veteran NASA astronauts have reported crew conflict during previous space travels. Understanding the potential negative impacts of interpersonal and intrapersonal issues on spaceflight and analog environments is critical for identifying actions required to help crewmembers succeed during new types of missions (e.g., Mars Missions). Few individuals have spent one year or longer in isolated and confined environments, and a Mars Mission could be as long as three to five years in duration. Observations and "lessons learned" from previous space missions and from analog environments are critical sources of information required to inform these efforts. In preparation for Exploration Missions, BHP research focuses on preventing and mitigating the risk of performance errors due to inadequate Team Cohesion and Performance, Inadequate Selection/Team Composition, Inadequate Training, and Poor Psychosocial Adaptation. Monitoring tools, countermeasures, training requirements, and selection recommendations are needed to aid flight crews and ground support teams.

Priority

Lunar Outpost Mission: Desirable to Quantify and Reduce Prior to the Lunar Mission.

Mars Mission: Important to Quantify and Reduce Prior to the Mars Mission.

Gaps

BHP 2.1.4: What is the experience of spaceflight crews regarding team cohesion, psychosocial adaptation, and training? (Priority 1)

The behavioral health experience of crews has not been systematically documented. This approach will inform the development of strategies for improving crew cohesion and communication, as well as adapting tools or measures to help monitor, detect, and prevent potential problems.

Activity:

Systematic Query: Crew History Report

2008:

Review of existing crew information and literature from analogs to examine small groups in extreme environments.

2009:

Develop questionnaire for current and future long-duration crews regarding their experiences, emphasizing interpersonal factors.

2009-Constellation Operations:

Implement questionnaire and analysis.

Product/Deliverables:

1) Crew History Report - provides recommendations based on existing spaceflight and analog experience of crews, including training, in-flight, and post-flight events.

2) Systematic procedure for collecting behavioral health data regarding interpersonal relations and crew dynamics from returning long duration astronauts.

3) Updates to Standards, if applicable.

Required Delivery Milestone:

Initial Crew History Report based on current anecdotal evidence and analog evidence delivered in 2008. Systematic procedure / questionnaire developed in 2009. Updates to Crew History Report made once thirty subjects have been evaluated, with subsequent updates following every four years. Report/Recommendations required by 2013 for Mission Ops Requirements Definition and 2023 for Lunar Habitat Mission Ops. Standards update in 2012.

Required Platforms:

Ground based data collection.

Project/Organization Responsible for Implementation of Activity:

Directed Study, in collaboration with CB and SD

BHP 2.2.1: What are the most effective methods for maintaining crew cohesion and ground communication, to manage and resolve conflict in space? (Priority 1)

Given the extended duration and confinement of Exploration Missions, strategies to promote crew cohesion and effective communication will be needed. Development of strategies and countermeasures, including development of training protocols, and new monitoring methods and tools may address this gap.

Activity:

Optimal Conflict Management

NSBRI funded the development of a technology that guides astronauts through conflict resolution.

2009-2012:

The effectiveness of this technology should be evaluated in analogs, such as the Antarctic, where groups of individuals are stationed for months at a time, in extreme, isolated environments where conflict has been known to occur.

2013-2015:

The technology should then be made available on ISS, and its effectiveness with astronauts, when used, should be evaluated.

If flight data collected reveals that additional countermeasures are needed to address cohesion and communication, additional studies will be developed to help design and test new strategies.

Product/Deliverables:

1) Technologies that provide conflict management support and guidance for crewmembers, particularly for autonomous operations.

2) Updates to Standards, if applicable.

Required Delivery Milestone:

In-flight validation of Conflict Management Technology to begin in 2012, with technology delivered by 2014. Standards update in 2012.

Required Platforms:

Conflict management technology to be evaluated in analogs, including the Antarctic. Flight validation of technology to occur on ISS.

Project/Organization Responsible for Implementation of Activity: NSBRI

<u>Activity:</u>

Optimal Conflict Management

2009:

Conduct a review of best practices for optimal communication strategies, between and within groups, from the military and other agencies.

2010-2012:

Obtain and analyze data of communications between space and ground crews, in order to develop recommendations for improved communication strategies related to performance of mission objectives.

2008-2013:

Conduct lab studies that examine the impact of environmental stressors, incentives, and crew configuration changes on communication and performance within simulated space crews and between simulated space and ground crews.

Product/Deliverables:

1) Recommendations for optimal communication strategies

2) Updates to Standards, if applicable.

Required Delivery Milestone:

Mission Ops to be informed by 2013 with Recommendations for Optimal Communication Strategies, in preparation for Mission Ops Requirements Definition, due in 2013. Standards update in 2012.

Required Platforms:

Analysis of ISS/MOD communications can be collected / analyzed from the ground. Conflict management technology to be evaluated in analogs, including the Antarctic. Flight validation of Recommendations to occur on ISS.

Project/Organization Responsible for Implementation of Activity:

Directed Studies (Review and ISS/MOD task); NSBRI (Lab studies)

Activity:

Social Support System for Exploration Missions

Practical ways to sustain support system to reduce negative health impact. Assessment of up and coming technologies.

2013-2017

TBD

Product/Deliverables:

1) Recommendations for optimal support system for Exploration

2) Updates to Standards, if applicable.

Required Delivery Milestone:

Mission Ops to be informed by 2017 with Recommendations for Optimal Support System in preparation for Lunar Habitat Mission Ops Operation, due in 2023. Standards update.

Required Platforms:

Ground studies. TBD

Project/Organization Responsible for Implementation of Activity:

NSBRI

BHP 2.3.1: What are the best methods for training crews for maintaining cohesion and optimal performance during Exploration Missions? (Priority 1)

Crews on ISS are multicultural, and this diversity will most likely continue for Exploration Missions. Finding adequate time for crews to train together continues to remain a challenge. These factors make it essential to determine what acceptable alternatives to traditional team training methods (i.e. virtual team training) exist. In addition, the type of team training activities (role playing, etc.) and the duration of the training are important factors in designing the most efficient and effective training model. It is critical to capture what type, dose, style and length of training can most adequately cover multiple competencies to ensure efficiency of the astronauts' time while ensuring mastery of the required competencies.

Activity:

Training Studies

2009-2011:

Analog studies (and/or studies in operational environment) to validate optimal training methods. Analogs may include NEEMO and HMP.

2011-2012:

Study with MOD to assess training methods with ground teams.

2013-2015:

Evaluate Training Requirements during spaceflight to determine if Training Requirements are adequate.

If further Training Requirements are needed, ground based studies will commence and will be followed by a phase of in-flight validation and lunar studies.

Product/Deliverables:

1) Requirements, crew training for team cohesion and optimal performance.

2) Update to Standards, if applicable.

Required Delivery Milestone:

Update Standards 2012. Requirements for Mission Ops due by 2013. Study completed 2015 (status provided in 2013 with subsequent updates.)

Required Platforms

This effort involves analogs (NEEMO, HMP); study with MOD; and validation to require ISS.

Project/Organization Responsible for Implementation of Activity: NRA

BHP 2.1.1: What methods and technologies can be developed to monitor crew coping with the behavioral conditions of spaceflight? (Priority 2)

During Exploration Missions, and especially during a Mars Mission, real time communication between the crew and flight surgeons will not be available as it is now on ISS. Flight surgeons have stated the need for unobtrusive monitoring tools that are transparent to crews, require minimal crew time or effort, and that help detect if crews are having difficulties coping with the spaceflight environment.

The aim of the current Activity is to develop a tool that detects changes in crew cohesion that may be precursors of crew dysfunction and poor performance. Such a tool would evaluate, as a measure of crew cohesion, changes in communication patterns (e.g., ratio of positive affect to total communication for given period). The tool would enable in real-time, an objective evaluation of crew dynamics and scheduling of risk mitigation countermeasures, as needed.

Monitoring tools identified in the Risk of Behavioral and Psychiatric Conditions may also provide an assessment of team cohesion. These tools (e.g., voice acoustics and facial expression recognition) will be validated in ground studies through 2010, and validated in flight through 2012 (more information can be found in Gap 3.1.1).

Activity:

Develop Crew Communications Technology

Activities include evaluating various existing techniques for assessing team cohesion through crew communication, validating these techniques in analog and/or operational environments (i.e. during astronaut training), and validating on ISS.

Preferred techniques will be developed into Requirements for an automated, unobtrusive tool to be utilized during Exploration Missions.

If after undergoing flight validation, these techniques are found to be not effective, additional research to occur on ground and on ISS. New Requirements will then be delivered by 2023 for informing Mission Ops and Input to Mars Ops Development.

Product/Deliverables:

1) Requirements for Crew Communications Technology (unobtrusive, passive measures that assesses changes in crew communication patterns as a measure of modified cohesion).

2) Updates to Standards (if applicable).

Required Delivery Milestone:

Delivered for Mission Operations by 2013. Standards updates by 2012.

Techniques are required to inform Mission Ops by 2013.

Required Platforms:

Ground studies to adapt technology for spaceflight; analogs include NEEMO, Haughton Mars Project (HMP), and other Isolated, Confined and Extreme (ICE) Environments. Validate on ISS, as the ISS will emulate the transit environment to Mars.

Project/Organization Responsible for Implementation of Activity:

NASA ITA with Ames

Activity:

Assess Impact of Cultural and Other Factors on Crew Cohesion and Performance

2013-2017: Activities TBD

Product/Deliverables:

1) Recommendations based on evidence gathered

2) Updates to Standards (if applicable).

Required Delivery Milestone:

Delivered for Mission Operations by 2017. Techniques are required to inform Lunar Habitat Mission Ops by 2020.

Required Platforms:

Ground Studies TBD

Project/Organization Responsible for Implementation of Activity:

NSBRI

BHP 2.1.3: Does increased autonomy impact crew cohesion and performance? (Priority 2)

As crews begin operations for long duration missions beyond low Earth orbit, they will need to exercise increasing command and control of their daily activities. The distance for Mars Missions will result in loss of capability for real-time communication, downlink, and commanding. Likewise, the crew will have to augment and adapt their schedules based on real time changes in their schedules. Medical Operations has requested a study of crew autonomy while we are still in low Earth orbit, to identify (if any) the impact of increased autonomy on crew dynamics and performance.

<u>Activity:</u>

Autonomy Studies

2009:

Conduct Autonomy Workshop to examine preliminary results from analog studies and further define role of autonomy in Mars exploration and its effects on crew performance and crew dynamics.

2008-2009:

Conduct studies in NEEMO to evaluate impact of increased autonomy on cohesion and performance.

2008-2010:

Conduct studies in the Russian-Chamber 105 day study, observing impact of increased autonomy on cohesion and performance.

2011-2015:

Studies on ISS to observe crew performance and cohesion, working under a low autonomy condition versus a high autonomy condition.

If evidence exists that increased autonomy impacts crew dynamics and performance, the need for countermeasures in addition to what BHP has developed/is developing, will be considered.

Product/Deliverables:

1) Recommendations based on the impact (if any) of increased autonomy in analogs and spaceflight.

2) Input for ISS as needed.

3) Updates to Standards, if applicable.

Required Delivery Milestone:

ISS data collection to be completed by 2015. Mission Ops for Lunar Habitat missions to be informed in 2015.

Recommendations to Mission Ops for Lunar Habitat missions are due by 2023.

Required Platforms:

Requires analogs (NEEMO, RCS) and ISS.

Project/Organization Responsible for Implementation of Activity:

NRA/Directed Study

BHP 2.2.2: What are the most effective countermeasures for mitigating stress and deteriorated morale in order to optimize performance? (Priority 2)

<u>Activity:</u>

TBD

Product/Deliverables:

TBD

Required Delivery Milestone:

TBD

Required Platforms:

TBD

Project/Organization Responsible for Implementation of Activity:

TBD

BHP 2.3.2: What are the best methods and tools for selecting and composing crews for optimal team performance during Exploration Missions? (Priority 3)

Group cohesion plays an important role in team performance: cohesive teams perform higher than less cohesive teams. Research demonstrates team selection factors influence team cohesion; thus, it is important to examine and implement practices to secure the best crew composition for Exploration Missions. Therefore, BHP's third priority within the Team Risk addresses recommendations for astronaut selection and team composition for Exploration Missions.

Activity:

Crew Composition Studies

2009-2010:

Collaborate with BHP Ops.

2011:

Review of selection and composition in other agencies.

2012-2017:

Assess factors of ISS crew and how those are related to measures of cohesion and performance. Develop composition and selection recommendations for Exploration Missions.

Product/Deliverables:

1) Recommendations, composition and selection.
2) Update Standards.

Required Delivery Milestone:

Inform Mission Ops for Lunar Habitat missions in 2017. Recommendations required by 2023.

Required Platforms:

This effort is primarily ground studies and data mining effort. May require ISS and involve in-flight questionnaires and assessment of composition.

Project/Organization Responsible for Implementation of Activity:

Directed (Review); NRA (ISS Study)

Activity:

Measures for Selection /Composition for Exploration Missions

Study of individual and contextual factors and best measures and tools that predict psychosocial adaptation in the LDM environment, consistent with competencies as identified by Ops.

2010-2017: TBD

Product/Deliverables:

3) Recommendations, composition and selection.

4) Update Standards.

Required Delivery Milestone:

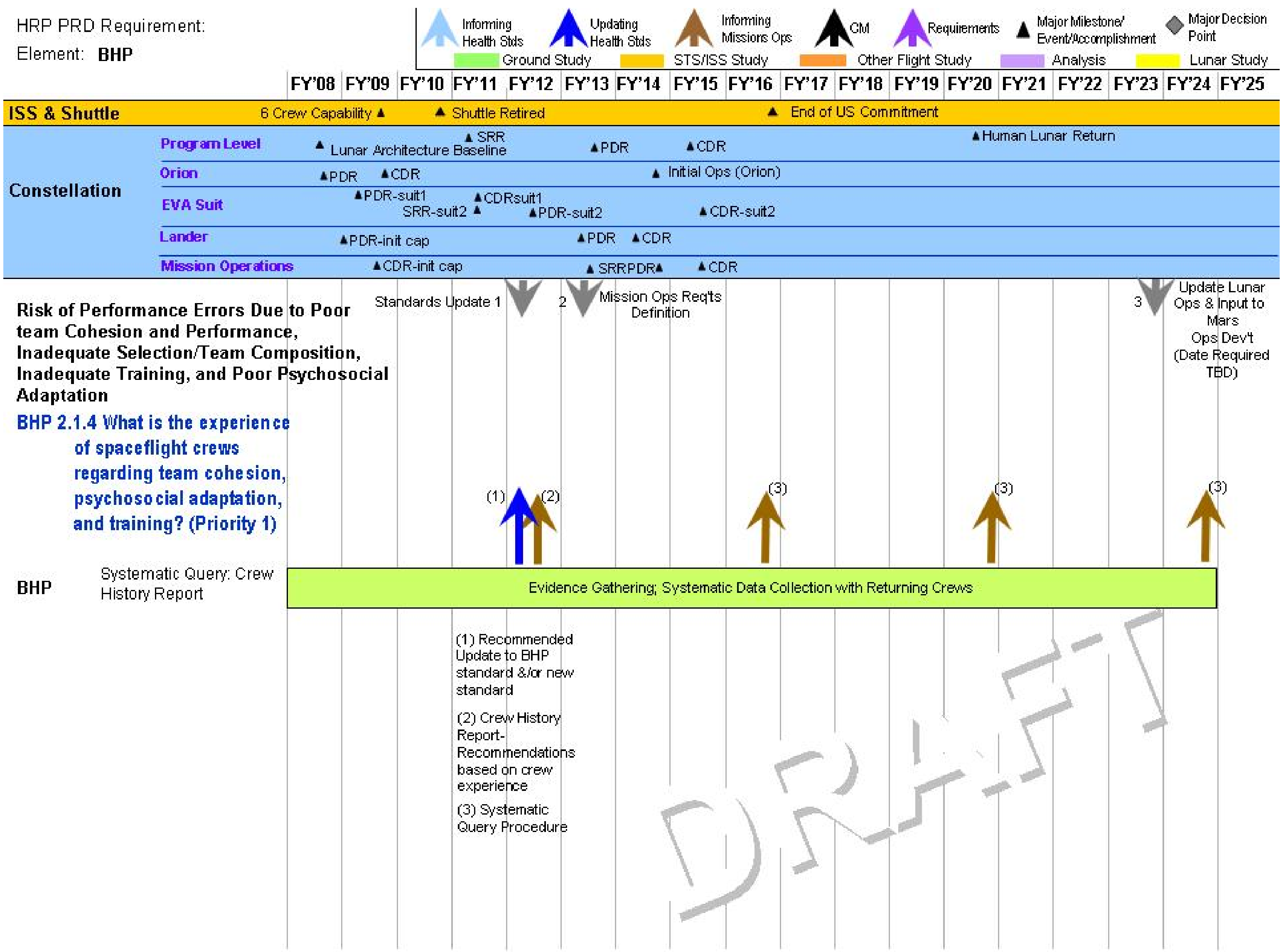
Inform Mission Ops for Lunar Habitat missions in 2017. Recommendations required by 2023.

Required Platforms:

This effort is primarily ground studies. TBD

Project/Organization Responsible for Implementation of Activity:

NSBRI


HRP PRD Requirement:
Element: BHP
Informing Health Stds
Updating Health Stds
Informing Missions Ops
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Major Milestone/ Event/Accomplishment
Major Decision Point
Ground Study
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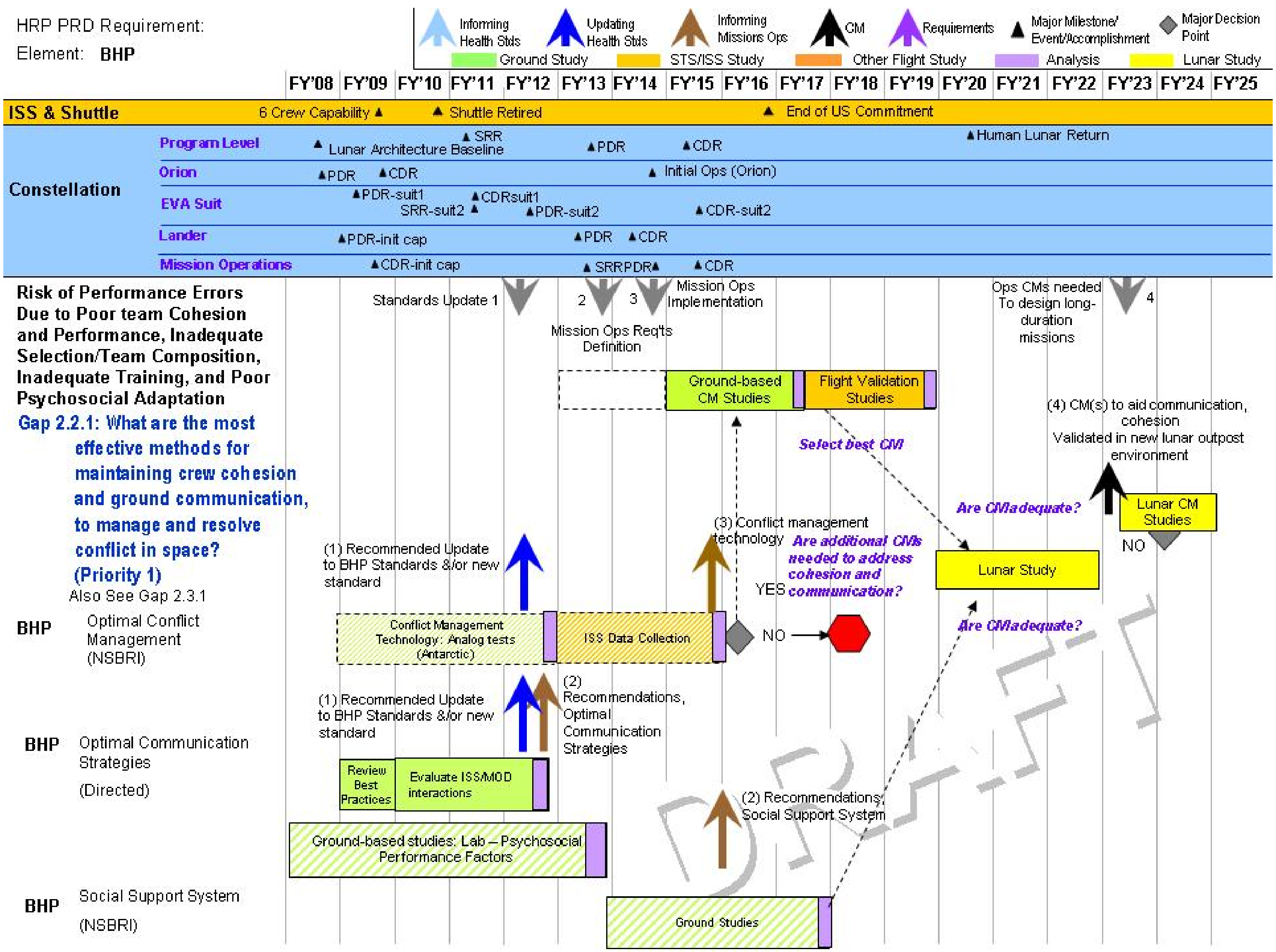
Mission Ops Req'ts Definition
3
Update Lunar Ops & Input to Mars Ops Dev't (Date Required TBD)
Risk of Performance Errors Due to Poor team Cohesion and Performance, Inadequate Selection/Team Composition, Inadequate Training, and Poor Psychosocial Adaptation
BHP 2.1.4 What is the experience of spaceflight crews regarding team cohesion, psychosocial adaptation, and training? (Priority 1)
(1)
(2)
(3)
(3)
(3)
BHP
Systematic Query: Crew History Report
Evidence Gathering; Systematic Data Collection with Returning Crews
(1) Recommended Update to BHP standard &/or new standard
(2) Crew History Report- Recommendations based on crew experience
(3) Systematic Query Procedure
DRAFT


HRP PRD Requirement:
Element: BHP
Informing Health Stds
Updating Health Stds
Informing Missions Ops
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Major Milestone/ Event/Accomplishment
Major Decision Point
Ground Study
STS/ISS Study
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Mission Operations
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Risk of Performance Errors Due to Poor team Cohesion and Performance, Inadequate Selection/Team Composition, Inadequate Training, and Poor Psychosocial Adaptation
Gap 2.2.1: What are the most effective methods for maintaining crew cohesion and ground communication, to manage and resolve conflict in space? (Priority 1)
Also See Gap 2.3.1
Standards Update 1
2
3
Mission Ops Req'ts Definition
Mission Ops Implementation
Ops CMs needed To design long-duration missions
4
Ground-based CM Studies
Flight Validation Studies
(4) CM(s) to aid communication, cohesion
Validated in new lunar outpost environment
Select best CM
Are CM adequate?
Lunar CM Studies
NO
(3) Conflict management technology
Are additional CMs needed to address cohesion and communication?
YES
Lunar Study
(1) Recommended Update to BHP Standards &/or new standard
BHP
Optimal Conflict Management (NSBRI)
Conflict Management Technology: Analog tests (Antarctic)
ISS Data Collection
NO
Are CM adequate?
(1) Recommended Update to BHP Standards &/or new standard
(2) Recommendations, Optimal Communication Strategies
BHP
Optimal Communication Strategies
(Directed)
Review Best Practices
Evaluate ISS/MOD interactions
Ground-based studies: Lab – Psychosocial Performance Factors
(2) Recommendations, Social Support System
BHP
Social Support System
(NSBRI)
Ground Studies
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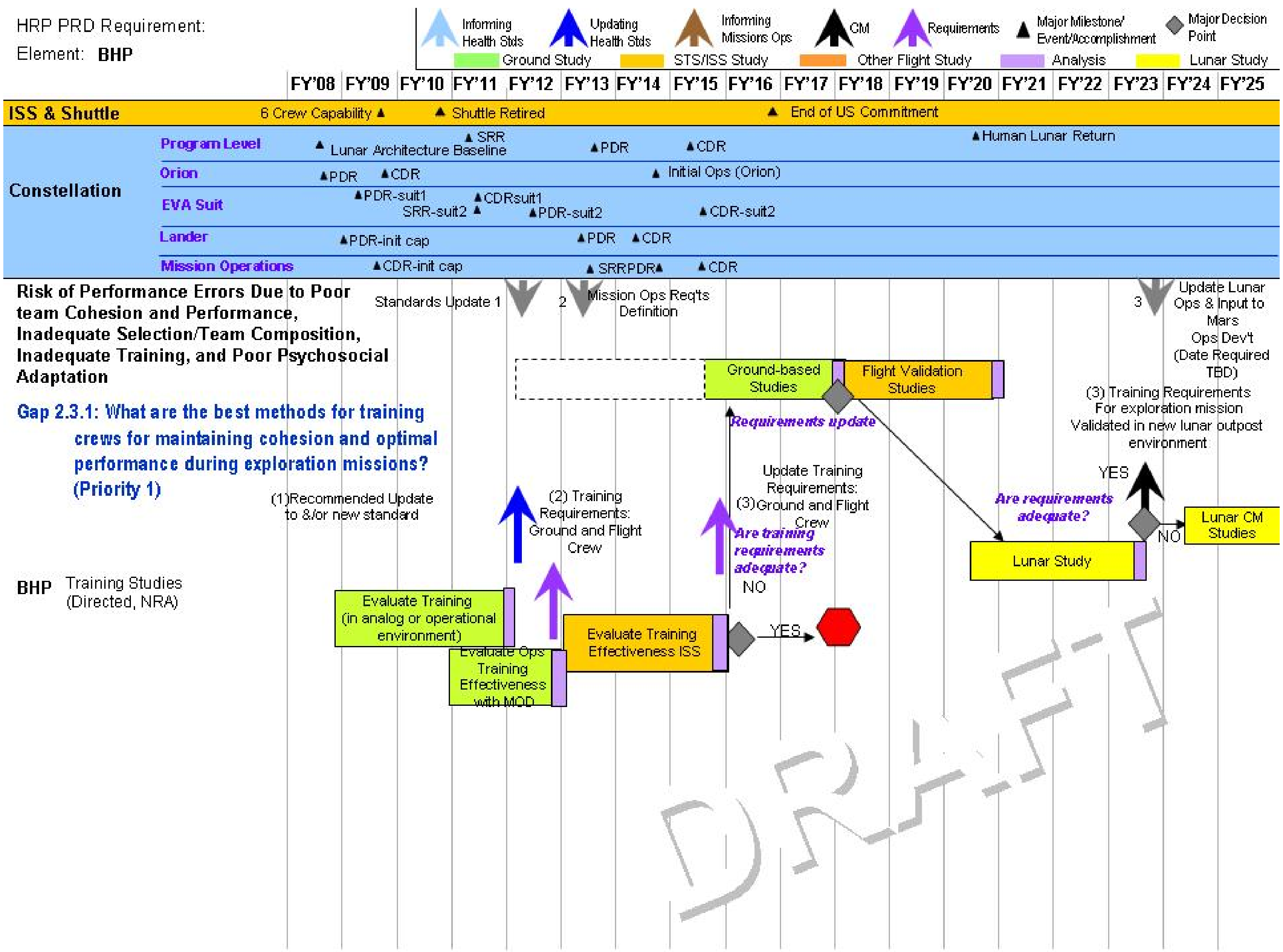
HRP PRD Requirement:
Element: BHP
Informing Health Stds
Updating Health Stds
Informing Missions Ops
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Major Milestone/ Event/Accomplishment
Major Decision Point
Ground Study
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CDR-suit2
Lander
PDR-init cap
PDR
CDR
Mission Operations
CDR-init cap
SRRPDR
CDR
Risk of Performance Errors Due to Poor team Cohesion and Performance, Inadequate Selection/Team Composition, Inadequate Training, and Poor Psychosocial Adaptation
Gap 2.3.1: What are the best methods for training crews for maintaining cohesion and optimal performance during exploration missions? (Priority 1)
Standards Update 1
2 Mission Ops Req'ts Definition
3 Update Lunar Ops & Input to Mars Ops Dev't (Date Required TBD)
Ground-based Studies
Flight Validation Studies
Requirements update
(3) Training Requirements For exploration mission Validated in new lunar outpost environment
Update Training Requirements: (3)Ground and Flight Crew
(1)Recommended Update to &/or new standard
(2) Training Requirements: Ground and Flight Crew
Are training requirements adequate?
NO
YES
Are requirements adequate?
YES
NO
Lunar CM Studies
Lunar Study
BHP Training Studies (Directed, NRA)
Evaluate Training (in analog or operational environment)
Evaluate Ops Training Effectiveness with MOD
Evaluate Training Effectiveness ISS
YES
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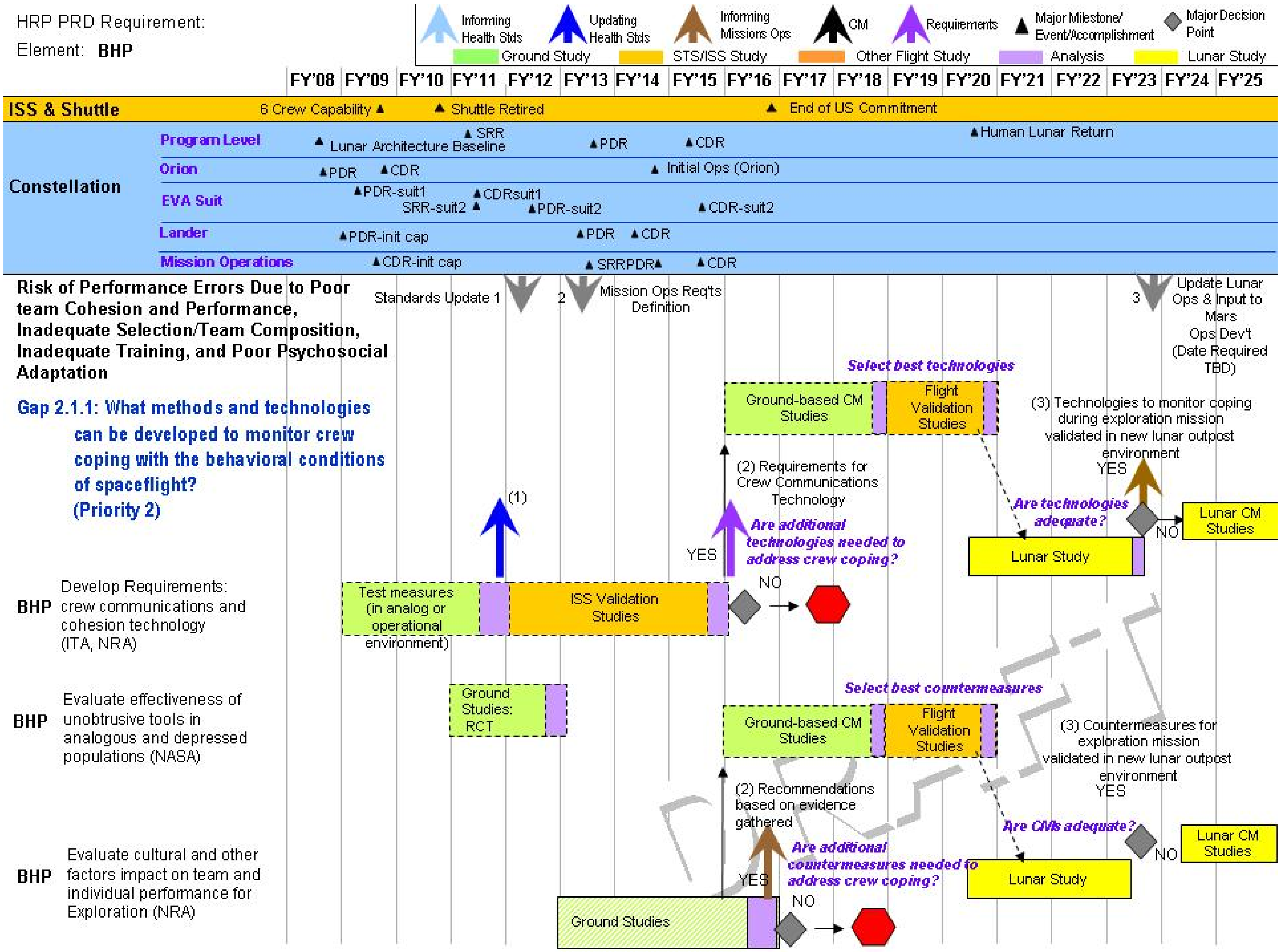
HRP PRD Requirement:
Element: BHP
Informing Health Stds
Updating Health Stds
Informing Missions Ops
CM
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Major Milestone/ Event/Accomplishment
Major Decision Point
Ground Study
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Risk of Performance Errors Due to Poor team Cohesion and Performance, Inadequate Selection/Team Composition, Inadequate Training, and Poor Psychosocial Adaptation
Gap 2.1.1: What methods and technologies can be developed to monitor crew coping with the behavioral conditions of spaceflight? (Priority 2)
Standards Update 1
2
Mission Ops Req'ts Definition
3
Update Lunar Ops & Input to Mars Ops Dev't (Date Required TBD)
Select best technologies
Ground-based CM Studies
Flight Validation Studies
(3) Technologies to monitor coping during exploration mission validated in new lunar outpost environment
YES
(2) Requirements for Crew Communications Technology
(1)
Are technologies adequate?
Lunar CM Studies
NO
Are additional technologies needed to address crew coping?
YES
Lunar Study
BHP Develop Requirements: crew communications and cohesion technology (ITA, NRA)
Test measures (in analog or operational environment)
ISS Validation Studies
NO
BHP Evaluate effectiveness of unobtrusive tools in analogous and depressed populations (NASA)
Ground Studies: RCT
Select best countermeasures
Ground-based CM Studies
Flight Validation Studies
(3) Countermeasures for exploration mission validated in new lunar outpost environment
YES
(2) Recommendations based on evidence gathered
Are CMs adequate?
Lunar CM Studies
NO
Are additional countermeasures needed to address crew coping?
YES
Lunar Study
NO
BHP Evaluate cultural and other factors impact on team and individual performance for Exploration (NRA)
Ground Studies
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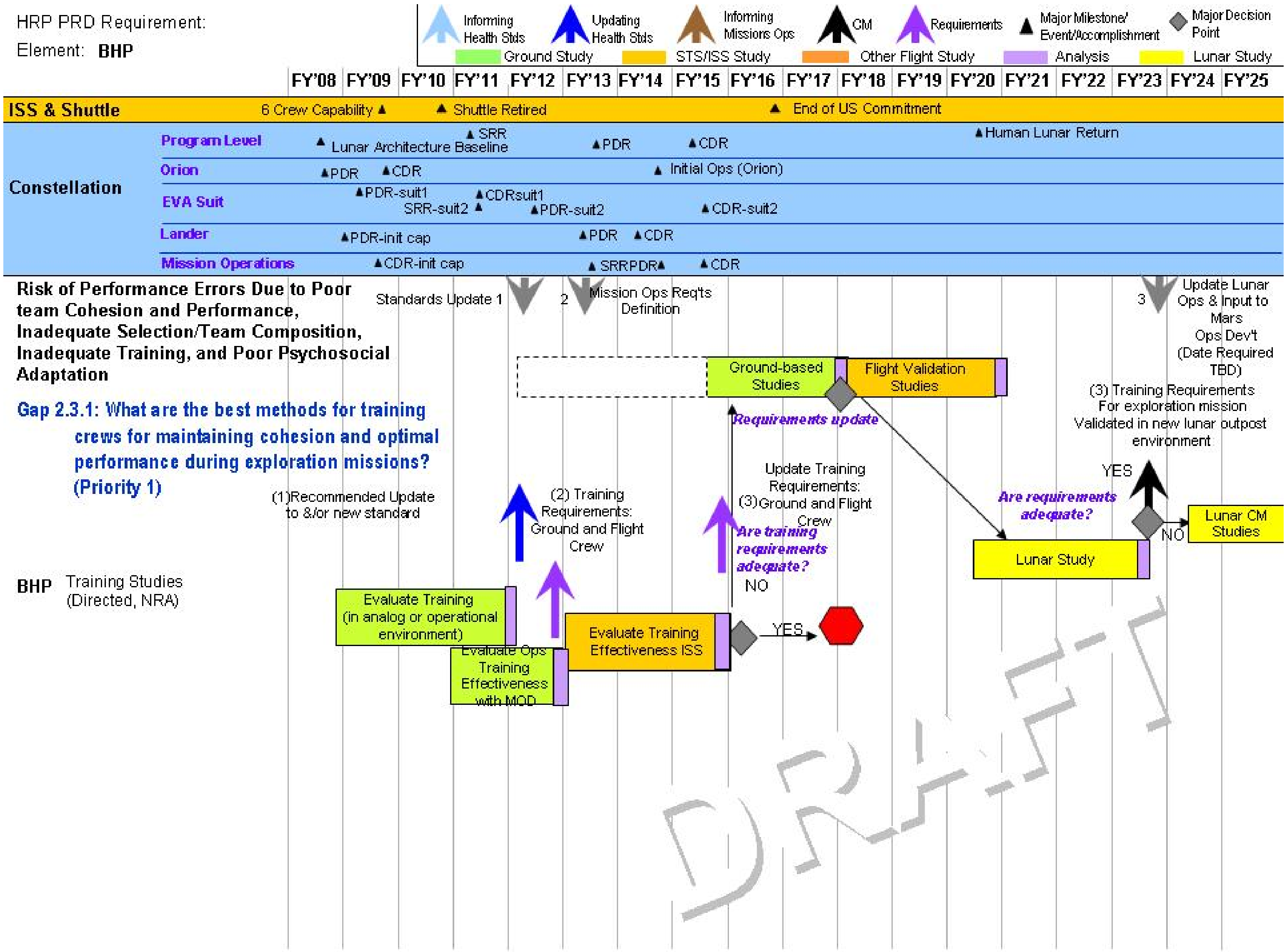
HRP PRD Requirement:
Element: BHP
Informing Health Stds
Updating Health Stds
Informing Missions Ops
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Risk of Performance Errors Due to Poor team Cohesion and Performance, Inadequate Selection/Team Composition, Inadequate Training, and Poor Psychosocial Adaptation
Gap 2.3.1: What are the best methods for training crews for maintaining cohesion and optimal performance during exploration missions? (Priority 1)
Standards Update 1
2
Mission Ops Req'ts Definition
3
Update Lunar Ops & Input to Mars Ops Dev't (Date Required TBD)
Ground-based Studies
Flight Validation Studies
Requirements update
(3) Training Requirements For exploration mission Validated in new lunar outpost environment
Update Training Requirements:
(3)Ground and Flight Crew
YES
Are requirements adequate?
NO
Lunar CM Studies
Lunar Study
(1)Recommended Update to &/or new standard
(2) Training Requirements: Ground and Flight Crew
Are training requirements adequate?
NO
BHP
Training Studies (Directed, NRA)
Evaluate Training (in analog or operational environment)
Evaluate Training Effectiveness ISS
YES
Evaluate Ops Training Effectiveness with MOD
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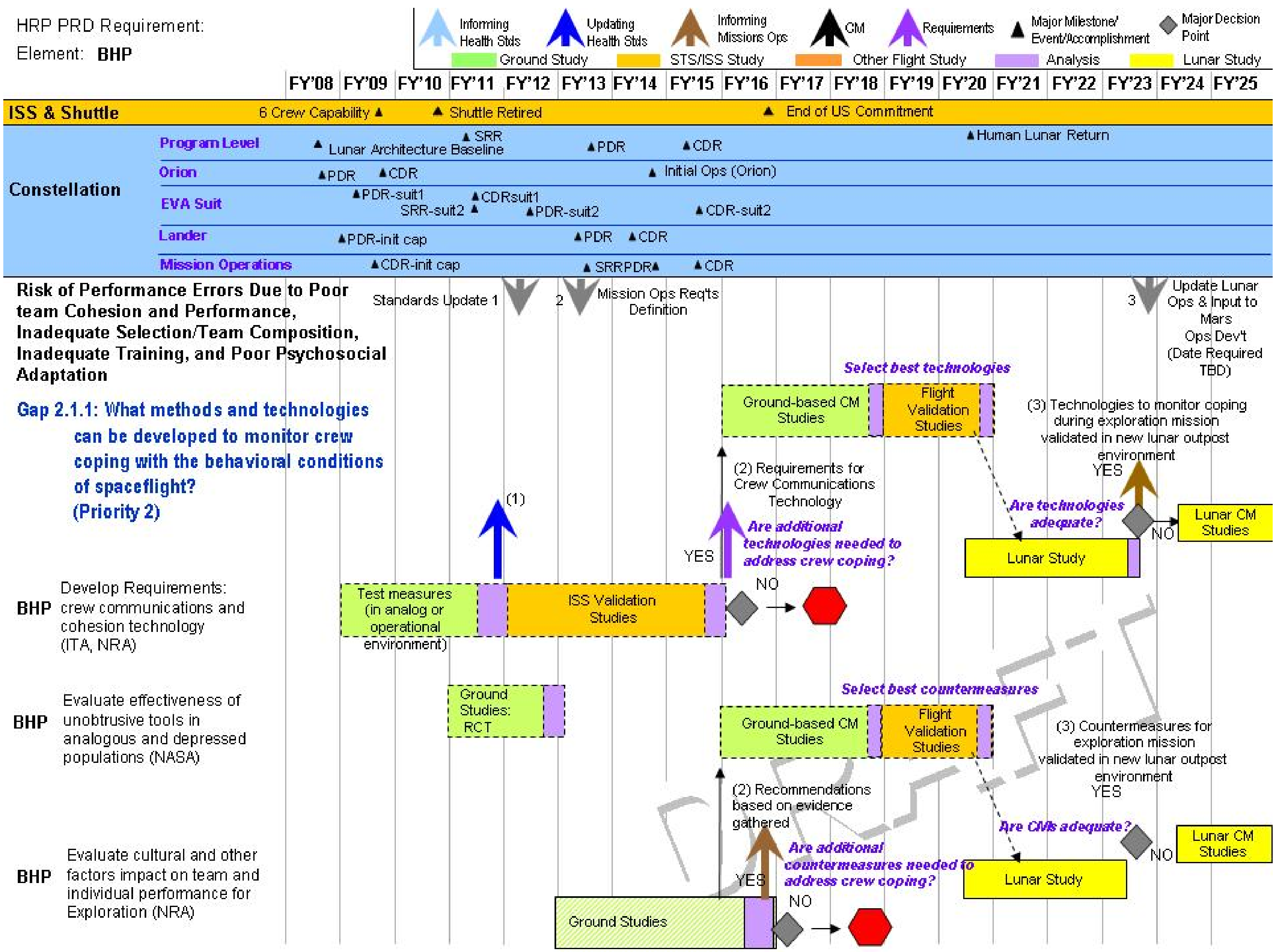
HRP PRD Requirement:
Element: BHP
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Updating Health Stds
Informing Missions Ops
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Major Milestone/ Event/Accomplishment
Major Decision Point
Ground Study
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Risk of Performance Errors Due to Poor team Cohesion and Performance, Inadequate Selection/Team Composition, Inadequate Training, and Poor Psychosocial Adaptation
Standards Update 1
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Mission Ops Req'ts Definition
3
Update Lunar Ops & Input to Mars Ops Dev't (Date Required TBD)
Gap 2.1.1: What methods and technologies can be developed to monitor crew coping with the behavioral conditions of spaceflight? (Priority 2)
Select best technologies
Ground-based CM Studies
Flight Validation Studies
(3) Technologies to monitor coping during exploration mission validated in new lunar outpost environment
YES
(2) Requirements for Crew Communications Technology
(1)
Are additional technologies needed to address crew coping?
YES
NO
Are technologies adequate?
NO
Lunar CM Studies
Lunar Study
BHP
Develop Requirements: crew communications and cohesion technology (ITA, NRA)
Test measures (in analog or operational environment)
ISS Validation Studies
BHP
Evaluate effectiveness of unobtrusive tools in analogous and depressed populations (NASA)
Ground Studies: RCT
Select best countermeasures
Ground-based CM Studies
Flight Validation Studies
(3) Countermeasures for exploration mission validated in new lunar outpost environment
YES
(2) Recommendations based on evidence gathered
Are CMs adequate?
NO
Lunar CM Studies
Are additional countermeasures needed to address crew coping?
YES
NO
Lunar Study
BHP
Evaluate cultural and other factors impact on team and individual performance for Exploration (NRA)
Ground Studies
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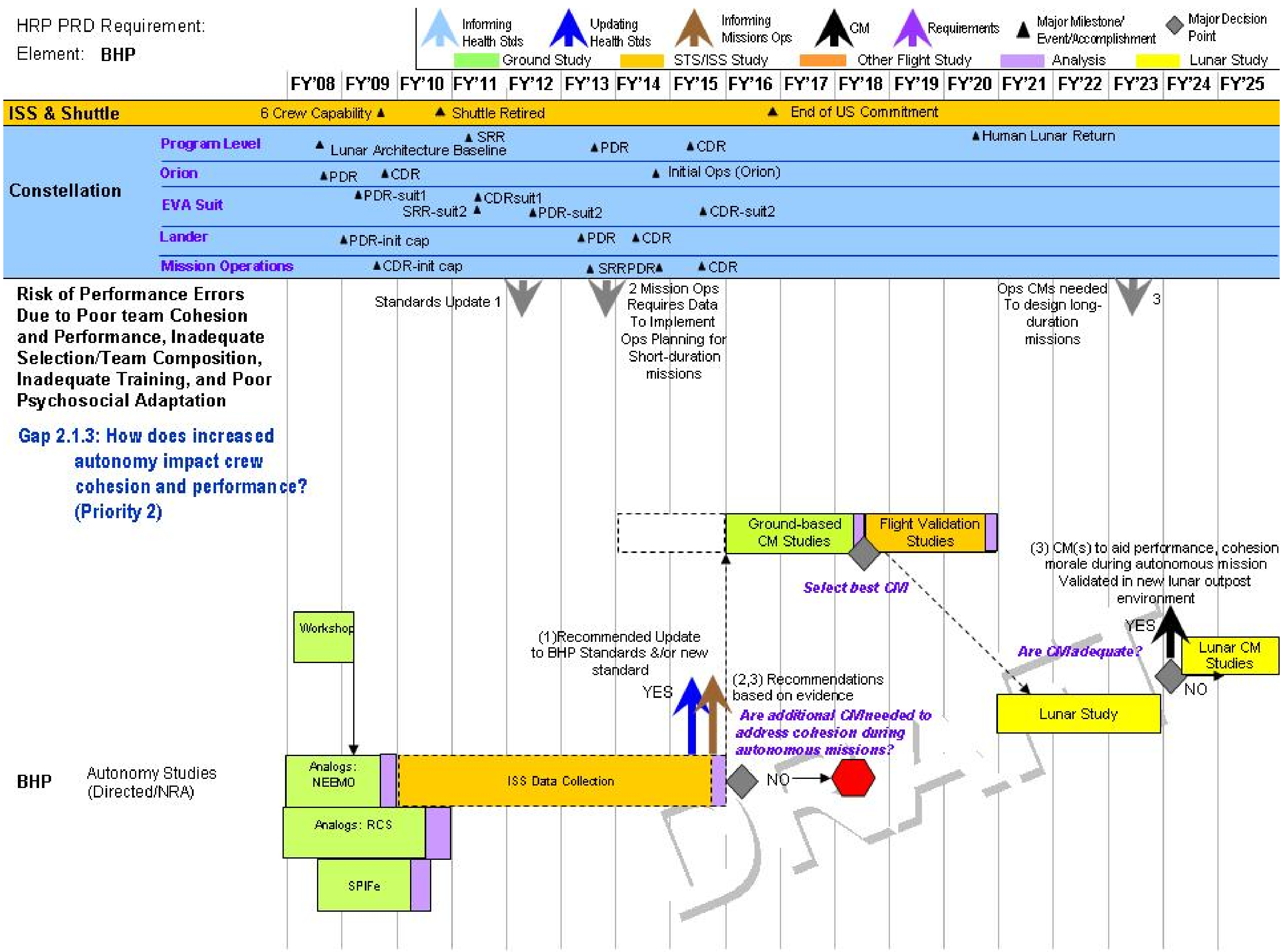
HRP PRD Requirement:
Element: BHP
Informing Health Stds
Updating Health Stds
Informing Missions Ops
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Major Milestone/ Event/Accomplishment
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Risk of Performance Errors Due to Poor team Cohesion and Performance, Inadequate Selection/Team Composition, Inadequate Training, and Poor Psychosocial Adaptation
Gap 2.1.3: How does increased autonomy impact crew cohesion and performance? (Priority 2)
Standards Update 1
2 Mission Ops Requires Data To Implement Ops Planning for Short-duration missions
Ops CMs needed To design long-duration missions
3
Ground-based CM Studies
Flight Validation Studies
Select best CM
(3) CM(s) to aid performance, cohesion morale during autonomous mission Validated in new lunar outpost environment
YES
Are CM adequate?
Lunar CM Studies
NO
Lunar Study
Workshop
(1)Recommended Update to BHP Standards &/or new standard
YES
(2,3) Recommendations based on evidence
Are additional CM needed to address cohesion during autonomous missions?
NO
BHP
Autonomy Studies (Directed/NRA)
Analogs: NEEMO
ISS Data Collection
Analogs: RCS
SPIFe
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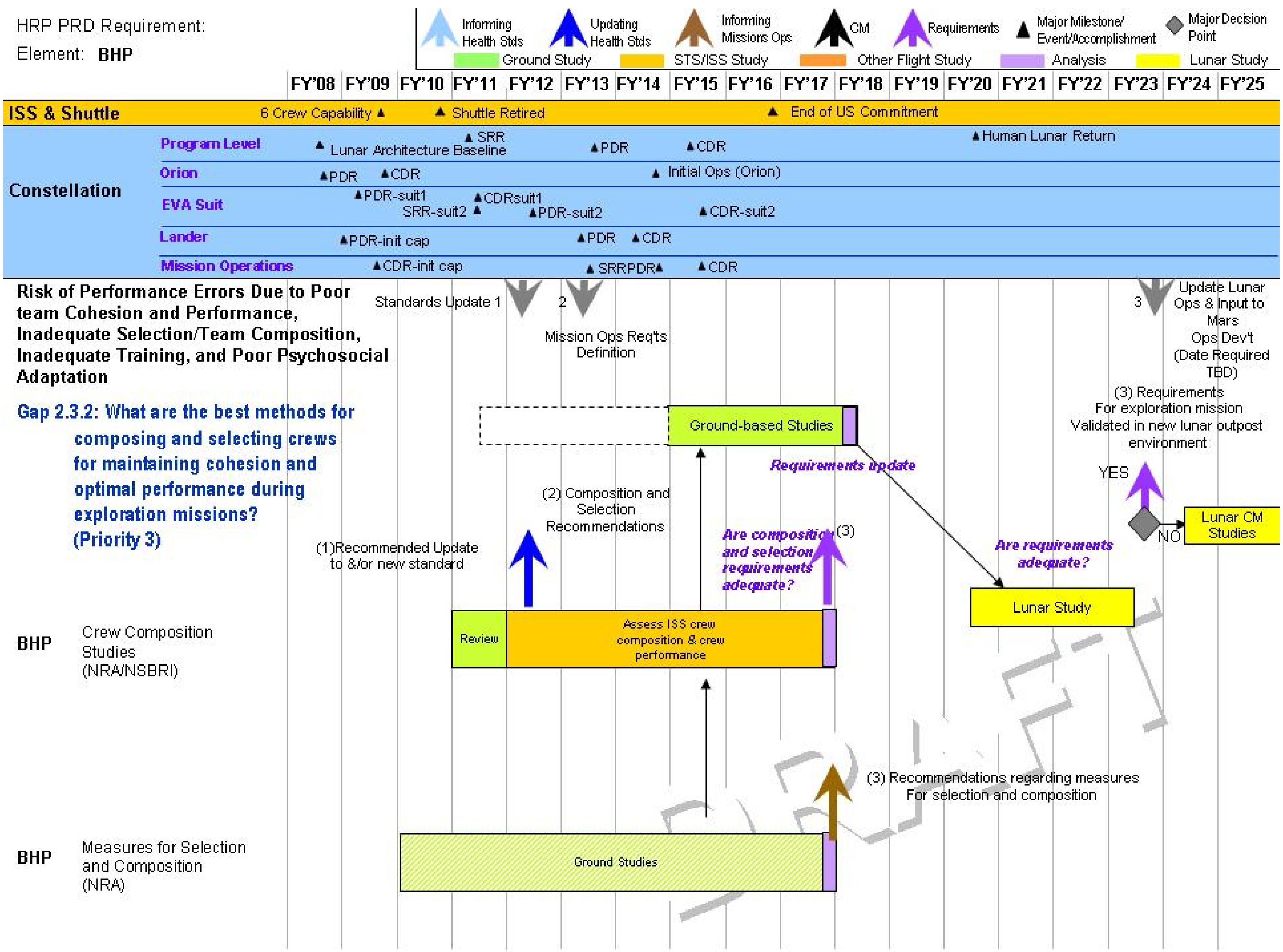
HRP PRD Requirement:
Element: BHP
Informing Health Stds
Updating Health Stds
Informing Missions Ops
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Risk of Performance Errors Due to Poor team Cohesion and Performance, Inadequate Selection/Team Composition, Inadequate Training, and Poor Psychosocial Adaptation
Gap 2.3.2: What are the best methods for composing and selecting crews for maintaining cohesion and optimal performance during exploration missions? (Priority 3)
Standards Update 1
2
Mission Ops Req'ts Definition
3
Update Lunar Ops & Input to Mars Ops Dev't (Date Required TBD)
(3) Requirements For exploration mission Validated in new lunar outpost environment
Ground-based Studies
Requirements update
YES
NO
Lunar CM Studies
(2) Composition and Selection Recommendations
Are composition and selection requirements adequate?
(3)
Are requirements adequate?
(1)Recommended Update to &/or new standard
Lunar Study
BHP
Crew Composition Studies (NRA/NSBRI)
Review
Assess ISS crew composition & crew performance
(3) Recommendations regarding measures For selection and composition
BHP
Measures for Selection and Composition (NRA)
Ground Studies
DRAFT